EECS 16A Designing Information Devices and Systems I
Spring 2022 Homework 8

This homework is due Friday, March 18, 2022 at 23:59. Self-grades are due Monday, March 21, 2022, at 23:59.

Submission Format
Your homework submission should consist of **one** file.

- `hw8.pdf`: A single PDF file that contains all of your answers (any handwritten answers should be scanned).

Submit the file to the appropriate assignment on Gradescope.

1. Mid-semester Class Survey

Please fill out the EECS16A Mid-semester Class Survey (click here). We appreciate your feedback towards improving this class — this really helps us improve future semesters as well as latter parts of this class. This survey is completely anonymous.

An incentive to do this: If more than 70% of the class fills out this survey in full, we will add 1 point to everyone's MT1 score. If more than 80% of the class fills out this survey in full, we will add 2 poinst to everyone's MT1 score. Please note that EECS 47D students are not required to fill out the survey.

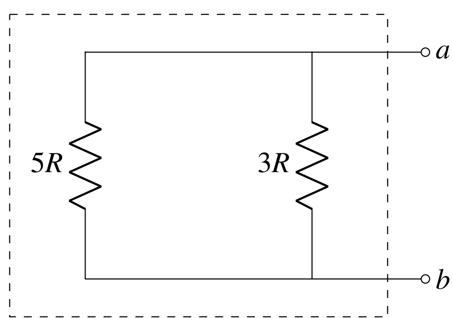
2. Reading Assignment

For this homework, please read Note 15. Note 15 covers superposition and equivalence, two very helpful techniques to help simplify circuit analysis.

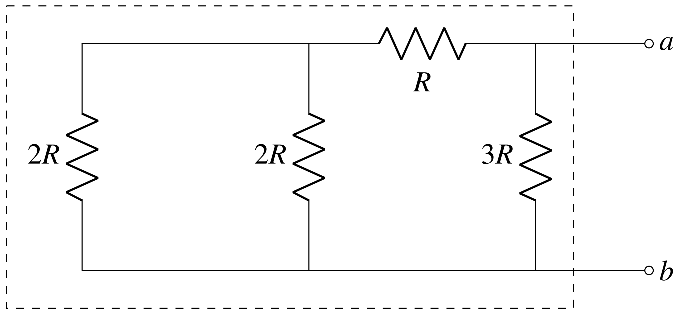
3. Equivalent Resistance

Learning Goal: *The objective of this problem is to practice finding the equivalent to a series/parallel combination of resistors.*

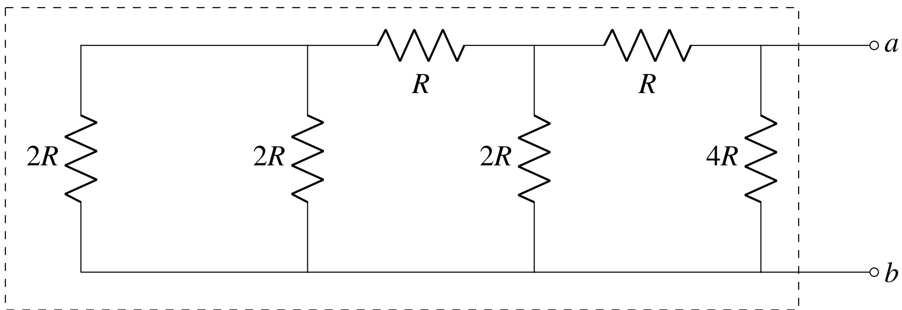
(a) Find the equivalent resistance looking in from points a and b. In other words, express the resistive network in the dashed box as one resistor.



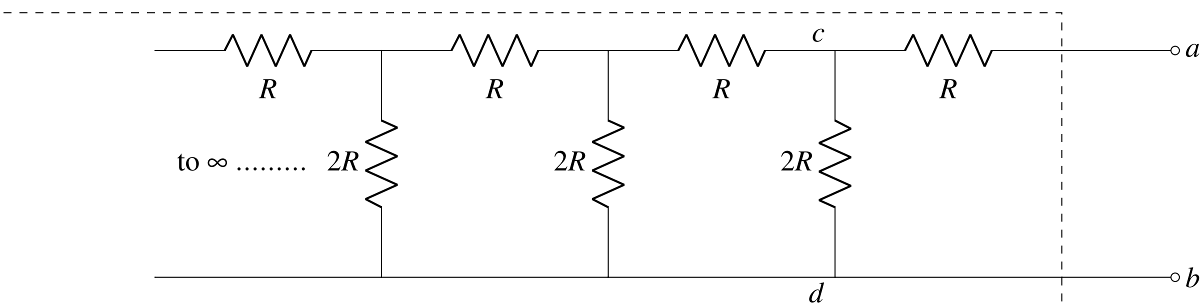
(b) Find the equivalent resistance looking in from points a and b. In other words, express the resistive network in the dashed box as one resistor.



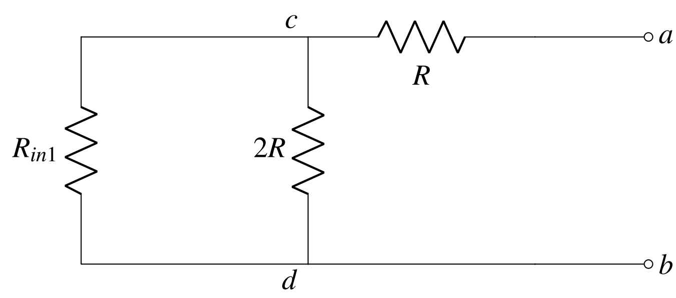
(c) Find the equivalent resistance looking in from points a and b. In other words, express the resistive network in the dashed box as one resistor.



(d) **(OPTIONAL, CHALLENGE)** Find the equivalent resistance for the infinite ladder looking in from points a and b. In other words, express the resistive network in the dashed region as one resistor. (*Hint: Let's call the resistance looking in from a and b as R_{in}, and the resistance looking to the left from points c and d as R_{in1}. Replace the entire circuit to the left of points c and d with a resistor whose value is given by R_{in1}. Find the relationship between R_{in} and R_{in1} using this circuit. Find another relationship between R_{in} and R_{in1} using the fact that the the ladder is infinite. For an infinite ladder, adding an another branch does not change the equivalent resistance. Think of this as a convergent infinite series.*)

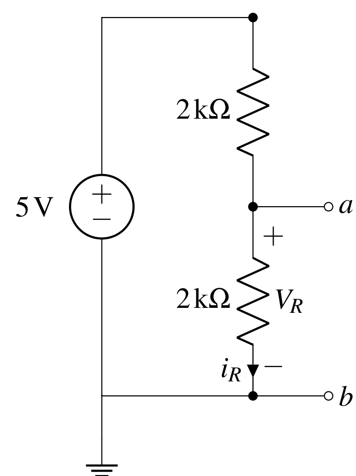


As a first step you can replace the circuit looking to the left from c and d by R_{in1}.

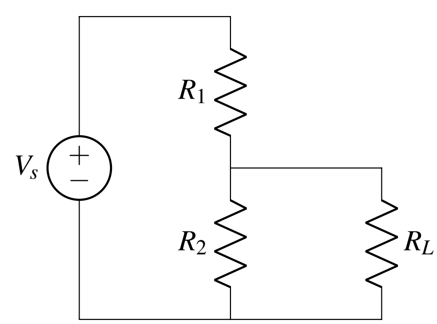


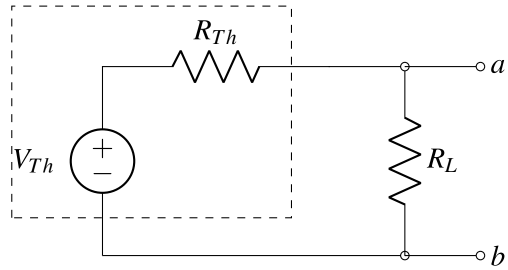
4. Why Bother With Thévenin Anyway?

(a) Find a Thévenin eqiuvalent for the circuit shown below looking from the terminals a and b. (*Hint: That is, find the open circuit voltage V_R across the terminals a and b. Also, find the equivalent resistance looking from the terminals a and b when the input voltage source is zeroed.*)



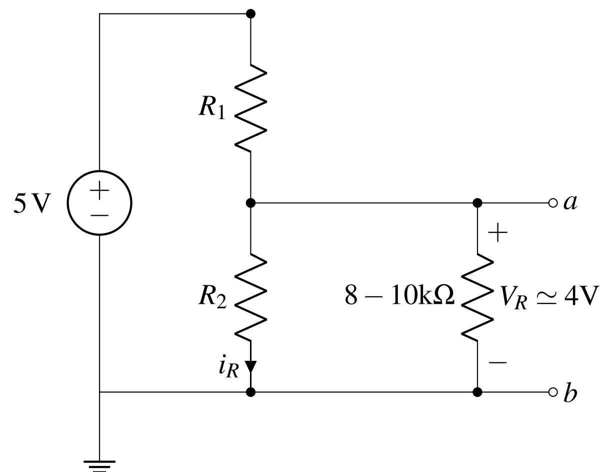
(b) Now consider the circuit shown below where a load resistor of resistance R_L is attached across the terminals a and b. Compute the voltage drop V_R across the terminals a and b in this new circuit with the attached load. Express your answer in terms of R_L. (*Hint: We have already computed the Thevenin equivalent of the unloaded circuit in part (a). To analyze the new circuit, attach R_L as the load resistance across the Thevenin equivalent computed in part (a), as shown in the figure below. One of the main advantages of using Thevenin (and Norton) equivalents is to avoid re-analyzing different circuits which differ only by the amount of loading.*)



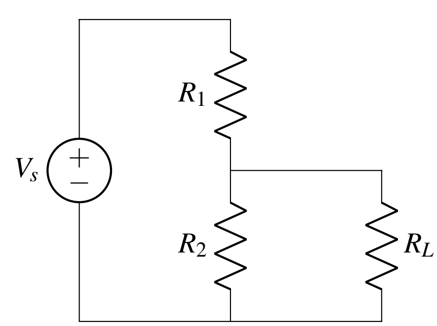


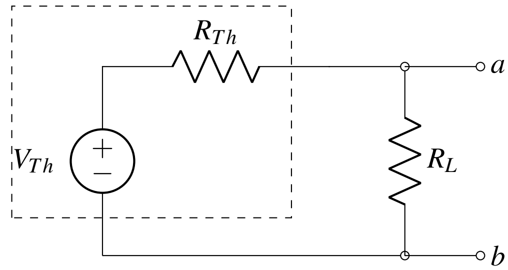
(c) Now compute the voltage drop V_R for three different values of R_L equal to $8/3\,\text{k}\Omega$, $8\,\text{k}\Omega$, $80\,\text{k}\Omega$? What can you comment on the value of R_L needed to ensure that the loading does not reduce the voltage drop V_R compared to the unloaded voltage V_R computed in part (a)?

(d) Say that we want to support loads in the range of $8\,\text{k}\Omega$ to $10\,\text{k}\Omega$. We would like to maintain $4\,\text{V}$ across these loads. How can we approximately achieve this by setting R_1 and R_2 in the following circuit?



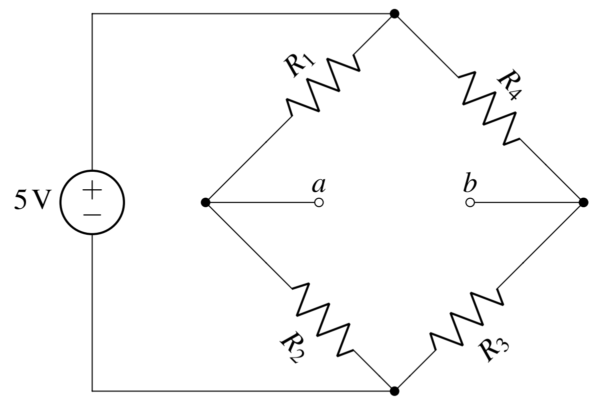
(e) Thus far, we have seen how to use Thevenin equivalents to compute the voltage drop across a load without re-analyzing the entire circuit. We would like to see if we can use the Thevenin equivalent for power computations. Consider the case where the load resistance $R_L = 8\text{k}\Omega$, $V_S = 5V$, $R_1 = R_2 = 2\text{k}\Omega$. Compute the power dissipated across the load resistor R_L both using the original circuitand the Thevenin equivalent. Are they equal? Now, compute the power dissipated by the voltage source V_s in the original circuit. Also, compute the power dissipated by the Thevenin voltage source V_{Th} in the Thevenin equivalent circuit. Is the power dissipated by the two sources equal?





5. Wheatstone Bridge

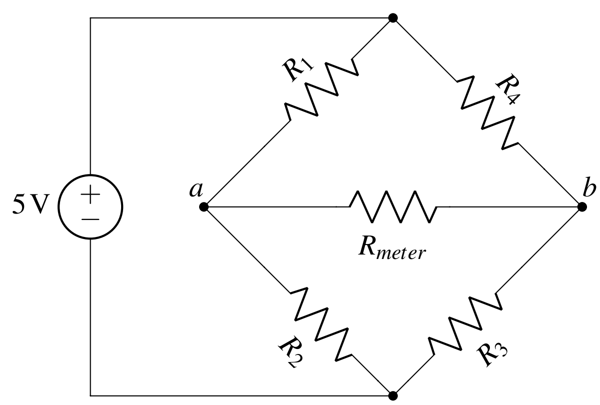
Thévenin equivalence is a powerful technique we can use to analyze the Wheatstone bridge circuit shown below. This circuit is used in many sensor applications where resistors R_1, R_2, R_3, R_4 are varying with respect to some external actuation. For example, it can be used to build a strain gauge or a scale (remember Fruity Fred from HW 7). In that case the resistors R_1, R_2, R_3, R_4 would vary with respect to a strain caused by a force, and the Wheatstone Bridge circuit would translate that variation into a voltage difference across the "bridge" terminals a and b. Assume that $R_1 = 2\,\text{k}\Omega$, $R_2 = 2\,\text{k}\Omega$, $R_3 = 1\,\text{k}\Omega$, $R_4 = 4\,\text{k}\Omega$



(a) Calculate the voltage V_{ab} between the two terminals a and b.

(b) Next, draw the Thévenin equivalent of the Wheatstone bridge circuit.

(c) Now assume that you are trying to measure the voltage V_{ab} using a voltmeter, whose resistance is R_{meter}, so you end up with the circuit below.

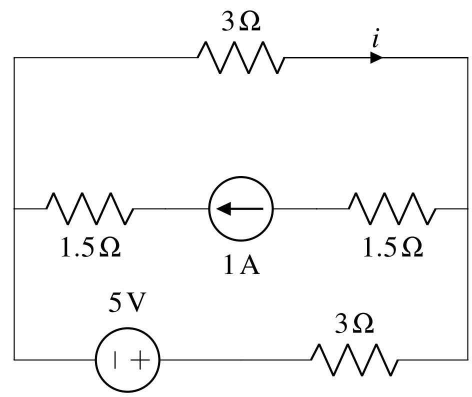


Unfortunately, you voltmeter is far from ideal, so $R_{meter} = 4k\Omega$. Is the voltage V_{ab} you found in part (a) equal to the new voltage $V_{R_{meter}}$ across the voltmeter resistor? Why or why not? Calculate the current $I_{R_{meter}}$ through the voltmeter resistor and the voltage $V_{R_{meter}}$ across the meter resistor.

6. Superposition

Learning Goal: *The objective of this problem is to help you practice solving circuits using the principles of superposition.*

Find the current i indicated in the circuit diagram below using superposition.



7. Homework Process and Study Group

Who did you work with on this homework? List names and student ID's. (In case you met people at homework party or in office hours, you can also just describe the group.) How did you work on this homework? If you worked in your study group, explain what role each student played for the meetings this week.